Assessing Global Climate Response of the NCAR-CCSM3: CO2 Sensitivity and Abrupt Climate Change

NCCS USERS MEETING

Zhengyu Liu
University of Wisconsin-Madison
March 27, 2007

Project Overview

- **Project Participants**

- *Zhengyu Liu (UW-Madison),*
- *Betty L. Otto-Bliesner (NCAR)*
- *David J. Erickson (ORNL/DOE)*
- *Robert L. Jacob (ANL/DOE)*
- *Bob Tomas (NCAR)*
- *Feng He (UW-Madison)*

Outline

- Project Overview
- Project impact
- Project logistics

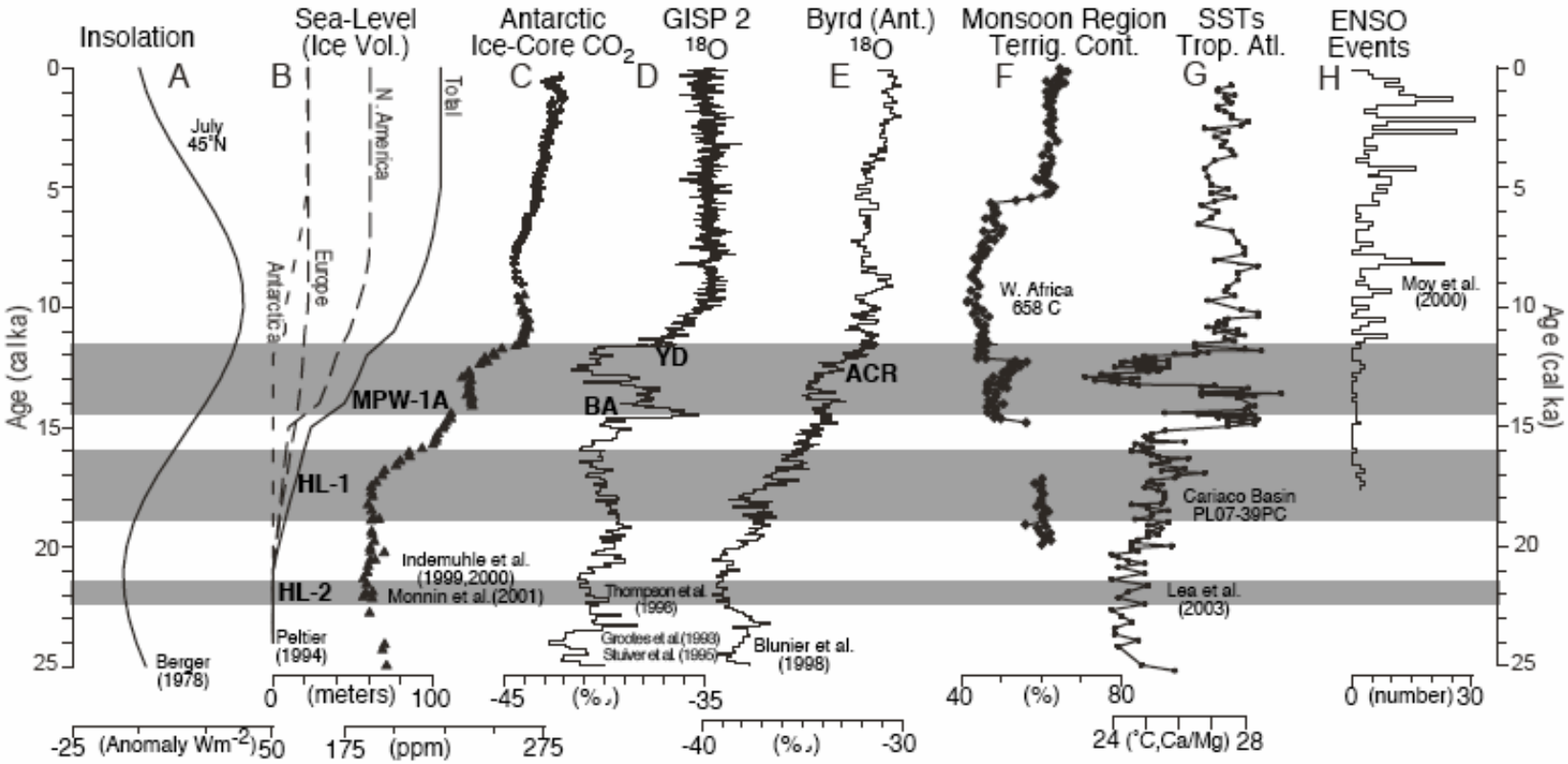
Project Overview

- The first **synchronously** coupled **transient** CGCM simulation of the past 21,000 years using NCAR-CCSM3
- Excellent opportunity to assess the CCSM3 simulation by comparing to proxy data and to address two fundamental questions on the future climate changes:

1) What is the sensitivity of the climate system to changes in greenhouse gases, notably CO_2?

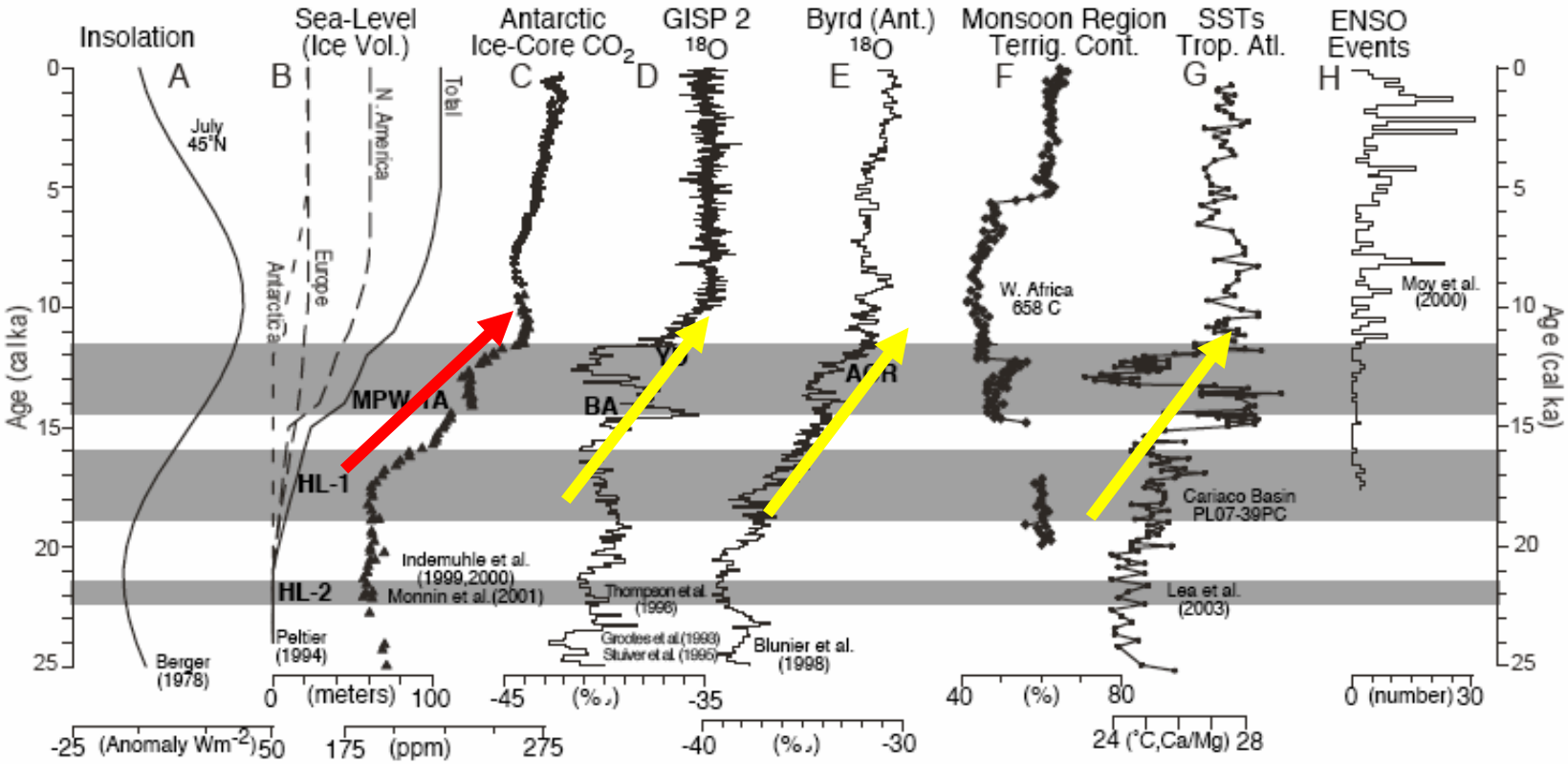
2) How does the climate system exhibit abrupt changes on decadal-centennial time scales?

Project Overview



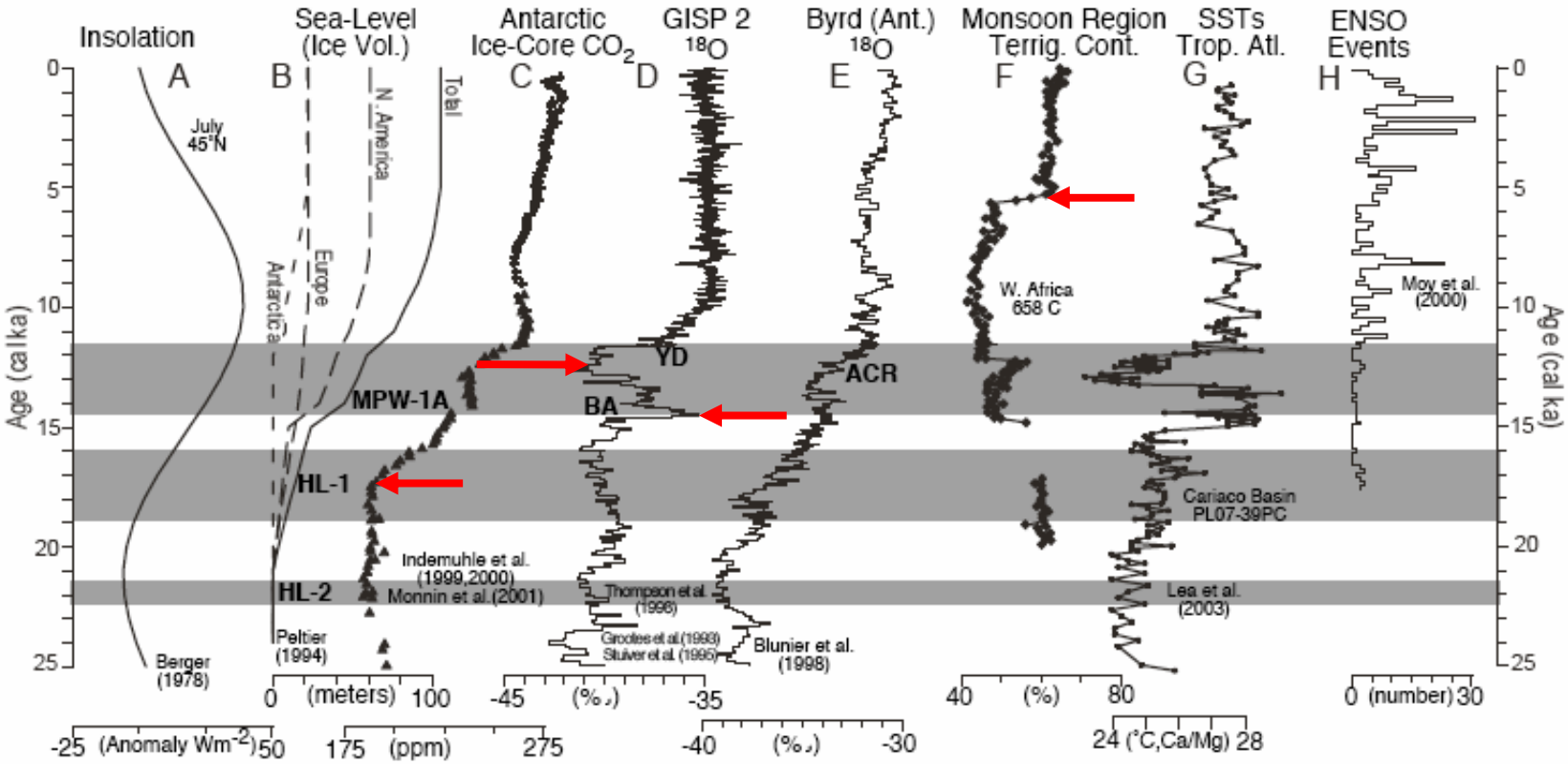
Time series of b.c.'s (forcings) and paleoclimate indicators

Project Overview



Trends in CO_2 forcing and paleoclimate indicators

Project Overview

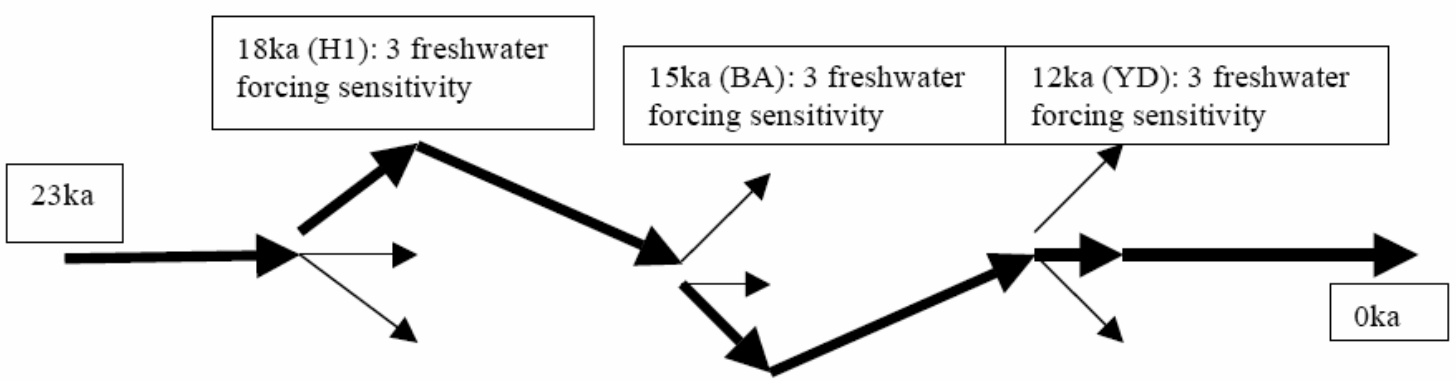


Some key events in these paleoclimate indicators

Project Overview

- **Major experiments**
- Unprecedented 21 ka synchronous coupled run using CCSM3 (T31X3)
- Prescribed CO2 and other GHG together with continental ice sheet and orbital forcing; Coastal line adjusted according to sea level rise
- Integrated from 23ka onward to provide time for spin-up

- Special considerations for H1, BA, YD events
- 2~3 sensitivity runs with same initial condition but different routing of freshwater pulses
- Select the run that closely resembles the observation to continue the transient experiment

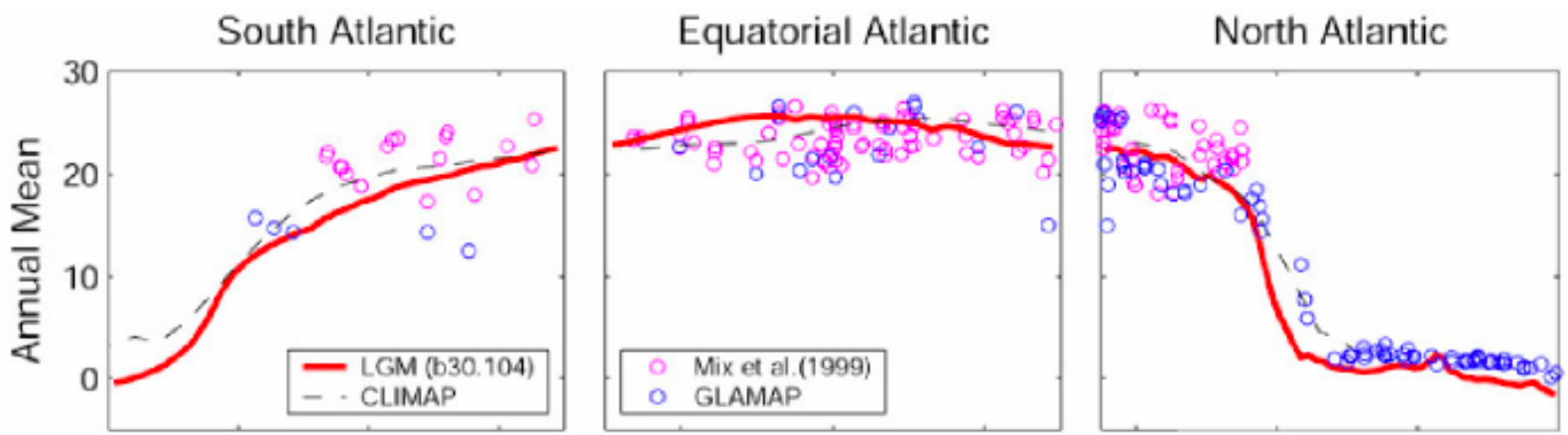


Project impact

- **Objective**
- Assessing the response to CO2 forcing: comparison with tropical SST
- Assessing the response of thermohaline circulation (THC): comparison with paleoceanography data
- Assessing abrupt change of high-latitude climate system: comparison with high temporal resolution data
- Assessing abrupt change of tropical climate-ecosystem: comparison with terrestrial data

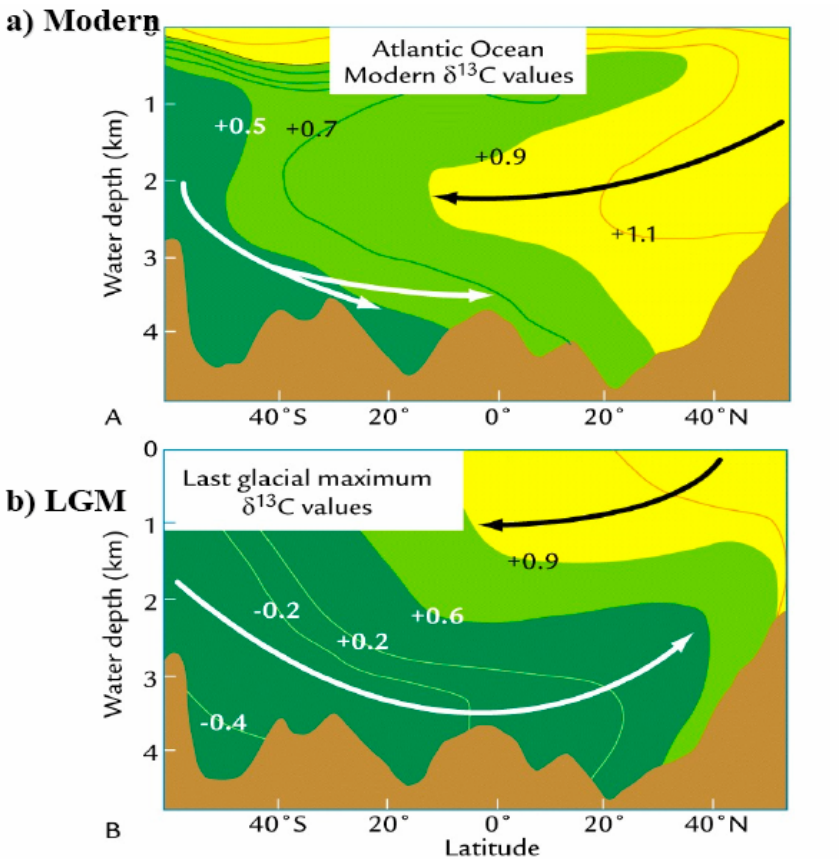
Assessing the response to CO2 forcing: comparison with tropical SST

- Recent study suggests CO2 seems to lead ice volume by several thousand years (Shackleton 2000; Vissel et al. 2003)
- Model simulations suggest 80% of SST change in the tropics is due to CO2 forcing (Manabe and Stouffer, 1980; Liu et al., 2005)
- Major deglaciation of last 21 ka provides excellent test on model sensitivity to CO2 forcing

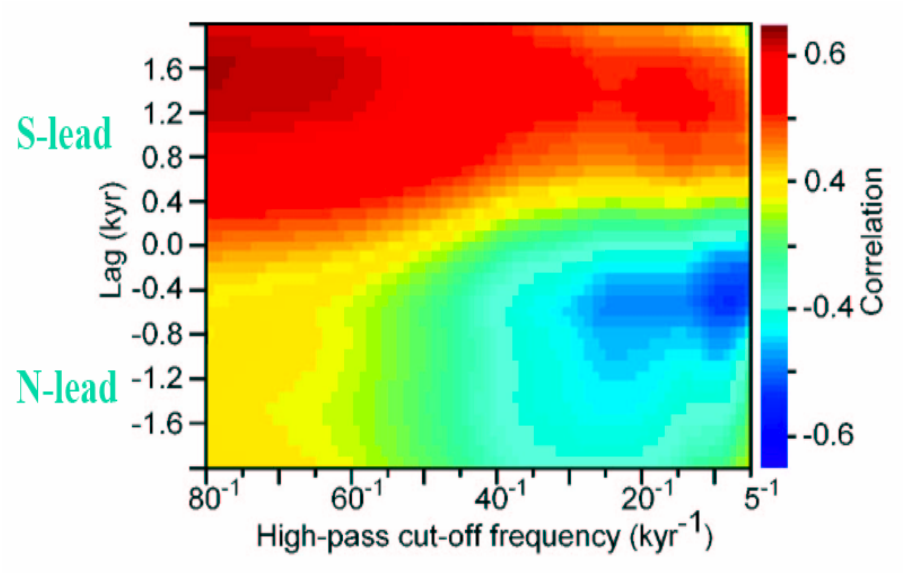


Otto-Bliesner et al. 2006

Assessing the response of thermohaline circulation (THC): comparison with paleoceanography data



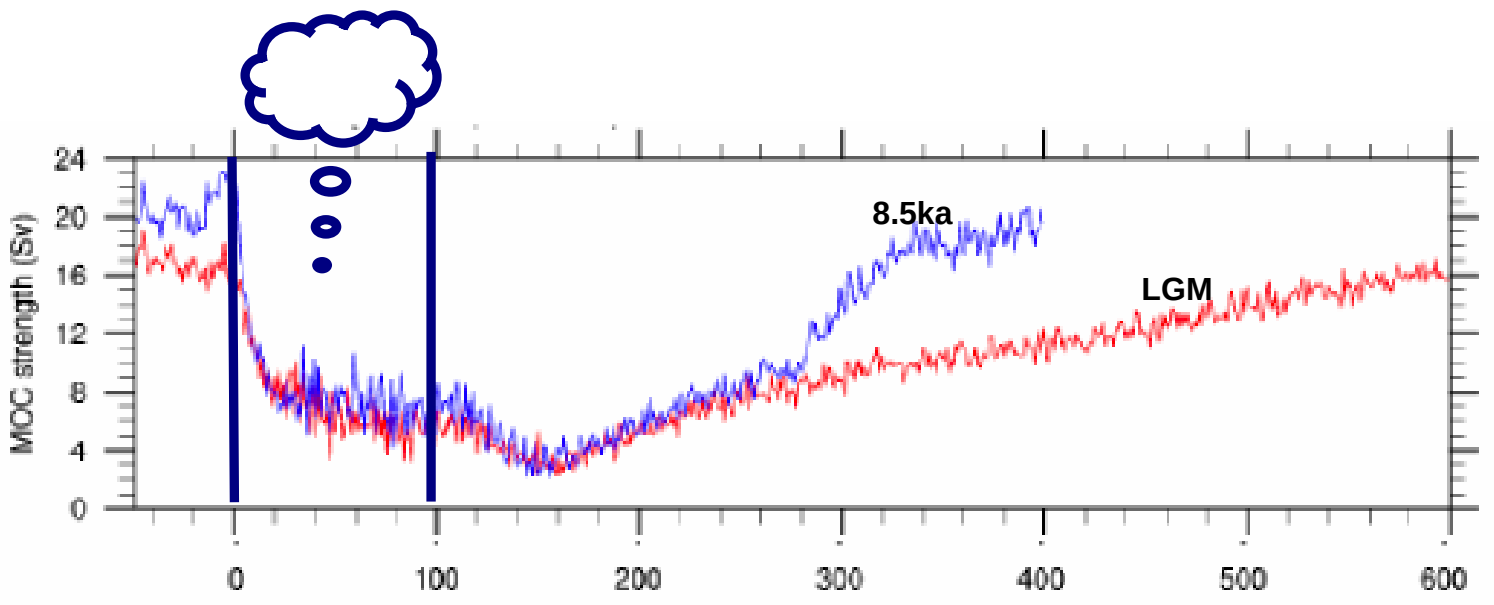
Ruddiman, 2001



Steig and Alley, 2003

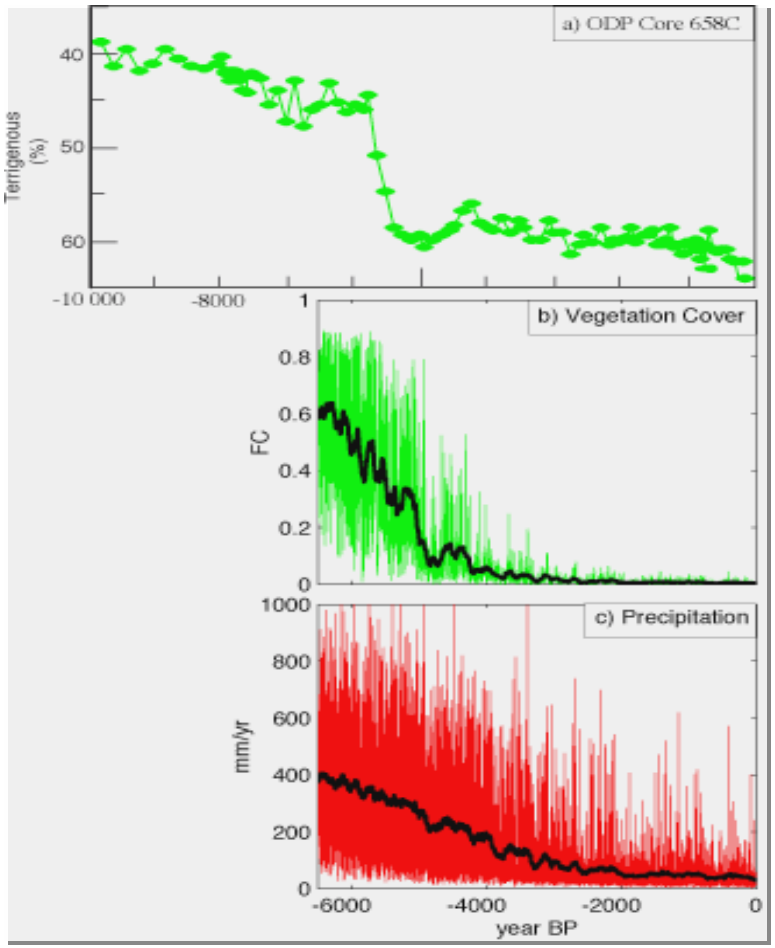
Assessing abrupt change of high-latitude climate system: comparison with high temporal resolution data

- THC variability strongly depends on background climate state
- Sensitivity experiments are performed to assess the robustness of model simulation to different river routine and freshwater forcing
- Data/model comparison provides the basis to select the best branch for continuing the transient simulation.



Assessing abrupt change of tropical climate-ecosystem: comparison with terrestrial data

- FOAM-LPJ 6.5 ka transient run suggests the collapse of north African ecosystem is due to strong climate variability and nonlinear bioclimatic threshold
- At 5 ka, we perform 4 TRANS-21 sensitivity experiments
- Two experiments start from slight different condition to test the role of natural climate variability on abrupt climate change
- Another two experiments use fixed vegetation at 6 ka and 0 ka to test vegetation feedback



Liu et al. 2006

Project impact

- It provides a strong test on CCSM3 for its climate sensitivity to greenhouse forcing as well as its capability for the simulation of abrupt climate changes
- It represents a great computational challenge for climate models, because there has been no model simulation of this length and complexity in the absence of flux adjustment.
- It will benefit tremendously the research community of both the data and modeling
- For data people, the CCSM3 model output can be readily compared with all proxy records to eliminate a large uncertainty in the absolute timing in many cases
- For modelers, the major simulation will provide a baseline experiment from which many sensitivity experiments can be further performed.
- This work will lay a foundation for a systematic testing of future generations of NCAR earth system models, including coupled ice sheets and biogeochemical (BGC) cycles.

Project logistics

- **Resources requested**
- Year 1: 420,000 processor*hours on Phoenix
- Year 2: 420,000 processor*hours on Phoenix
- **Storage requirements**
- Gigabytes of storage:
- Two programmers, each needs home directory 20 GB, scratch 250 GB storage
- Gigabytes or terabytes of mass storage: 544.8MB/month*37000years=20 TB,
- **Visualization needs?**
- 3D visualization tools

Project logistics (continued)

- **Development efforts**
- Code modification to be suitable for transient integration
- **Anticipated issues/problems in production run**
- 21ka transient simulation with synchronous coupling represents a great computational challenge for climate models, the model might have unexpected behavior
- **Anticipated interaction with the NCCS staff**
- We need close interaction with NCCS staff on model performance, data storage and visualization issues.

Reference

- Liu, Z., S. Shin, R. Webb, W. Lewis and B. Otto-Bliesner, 2005: Atmospheric CO2 forcing on glacial thermohaline and climate. Geophys. Re. Lett, 32, L02706, doi:10.1029/2004GL021929
- Liu, Z., Y. Wang, R. Gallimore, F. Gasse, T. Johnson, P. DeMenocal, J. Adkins, M. Notaro, J. Kutzbach, L. Wang, E. Ong and P. Behling, 2006a: Simulating the Transient Evolution and Abrupt Change of Northern Africa Atmosphere-Ocean-Terrestrial Ecosystem in the Holocene. Quatnery Science Review, in review.
- Otto-Bliesner BL, Brady EC, Clauzet G, Tomas R, Levis S, Kothavala Z, 2006: Last Glacial Maximum and Holocene Climate in CCSM3. Journal of Climate, 19, 2567-2583
- Ruddiman, W., 2001: Earth's Climate, Past and Future, W. H. Freeman & Co., 465pp.
- Shackleton, N., 2000: The 100,000-year ice-age cycle identified and found to lag temperature, carbon dioxide, and orbital eccentricity. Science, 289, 1897-1902.
- Steig E.J. and R. B. Alley, 2003: Phase relationships between Antarctic and Greenland climate records. Annuls of Glaciology 35, 451-456.
- Stouffer R. and S. Manabe, Equilibrium response of thermohaline circulation to large changes in atmospheric CO2 concentration. Climate Dynamics, 20, 759-773 (2003).
- Visser, K., R. Thunell and L. Stout, 2003: Magnitude and timing of Indo-Pacific warm pool during deglaciation. Nature, 421, 152-155